Detection of Very Weak Transmissions from Deep Space

Designers of future planetary missions often reduce transmitter power and oscillator stability requirements to reduce mission cost. These two reductions can make it much more difficult to detect weak signals from deep space.

Deep space telemetry has, from the start of the space program, been received using coherent tracking techniques. These techniques require the receiver to coherently recover the downlink carrier from the received signal. The recovery process uses a narrow carrier tracking loop in order to minimize the signal-to-noise ratio of the recovered carrier, which must typically be above 10 dB.

The new Block V receiver being installed in the Deep Space Network (DSN) can recover suppressed carrier signals and can utilize very narrow loop bandwidths - as narrow as 0.1 Hz. Unfortunately, operations at very narrow tracking loop bandwidths are quite sensitive to spacecraft oscillator stability. The 1 ow-cost oscillators planned for most future missions can force the usc of wider tracking loop bandwidths than otherwise desired, leading to reduced carrier tracking performance. This reduced performance can, in turn, lead to a significant increase in required spacecraft transmitter power.

To illustrate this point, consider a spacecraft at Mars with a "safe mode" requiring the transmission of telemetry through a 6 dB low gain antenna. If a 10 Hz tracking loop bandwidth must be used, a 30 W RF transmitter is required to receive any telemetry at all at a 70 m DSN station. If a 1 Hz bandwidth can be used, transmitter power can be reduced to 6 W RF. This result is somewhat independent of the data rate. (as long as it is -lo bps or less), since the power requirement is driven by the need to maintain an adequate carrier S NR rather than by telemetry SNR.

This paper recounts tests characterizing Block V performance with low cost oscillators and, for comparison, with Ultra Stable Oscillators. It presents tracking loop bandwidth recommendat ions based on actual tests with spacecraft oscillators.

This paper also considers alternative modulation techniques that could be used to track very weak telemetry signals at ranges beyond those at which the conventional coherent techniques are viable.